Problem No.9 – Meteorite

We interpreted the conditions of this problem in two possible ways:

1. the first case presupposed, that the mass of the meteorite is 10^6 kg in the moment of contact with photosphere (which is usually indicated as the solar surface).

2. the second case considered the fact that the meteorite had mass of 10^6 kg when it entered the solar corona.

The meteorite was supposed to be observed from the Earth's surface or terrestrial orbit. The possibility of sending out an observing station to the Sun (or placing it directly on the meteorite) was strictly excluded. We supposed that we know the trajectory of the meteorite exactly and therefore we are to aim it with a telescope in any time as well.

In our solution we took the advantage of a detailed report from the observation of the Howard-Koomen-Michels 1979 XI comet from Kreutz group. It passed by the Sun in its very close vicinity and lost its halo and comma at this juncture. This phenomenon was observed at Lomnické pleso observatory as changes in emission lines of FeII and SiII. This report gave us very useful information about processes in the solar atmosphere and it pointed at the most effective way of solving this problem.

At first we had to describe parameters of the meteorite (resp. its trajectory) such as its velocity and further its distance from Sun in dependence on time (from which is following dependence shown on Fig.15 – it is its integrated form). Another parameter we were interested in was the temperature of the meteorite in dependence on distance from the Sun. While deriving an expression showing this parameter we supposed that the meteorite is orbiting a certain distance from the Sun and is rotating rapidly. In this case – after some time – the state of dynamic equilibrium must occur, which means that all of the energy recepted from the Sun is equalled to the energy emitted by the meteorite. These two expressions set into an equation are easy to simplify and the temperature of the meteorite can be easily evaluated (Fig. 16,17). For the case of visual observvation it is useful as well to know the magnitude of the meteorite – its evaluation from Poggson's equation is very simple. The raw estimate of the rate of sublimation is useful as well (the time necessary to overload the thermal capacity and the head of sublimation of the meteorite found out from the solar emissional power in the certain distance).

The meteorite is supposed to be composed of iron, silicon (resp. its alloys) and ice - this is the most usual composition of such objects as meteorite are. At such high temperatures (see the graph of dependence of temperature on distance from the Sun) all the ice will already be evaporated. Because of the small size of the meteorite (globe-like shape with diameter about 10 m – density of meteorites is commonly around 2.10^3 kgm^{-3}) we can suppose, that this body is heated uniformly (and therefore we don't contemplate such effect as thermal conductivity etc.).

Methods of observation

Generally there are two possible methods of observing this phenomenon. The first, the visual one is enranged by the capabilities of presents terrestrial telescopes. Although the meteorite is a very feeble light source, this method is in some cases useful as well.

The second way is based on observing the emissional and absorptive lines of heavy metals (FeII, SiII). In this case we should find the area on the solar surface which will be affected and the change of the concentration of these ionized metals.

The First Case – The Fall into the Corona

No visual observation is now possible – the brightness of the meteorite will be far overshone by the corona. The evaporated gas (from the meteorite) will form a tunnel-like object that will be dispelling. Another case is possible as well: the meteorite will explode and its mass will be dispelled into some certain space (sphere-like). Let's say that we will observe the area of 100x100 km^2 (this area is really quite well observable). The ultimate depth under the solar surface that is still observable (or from which the solar spectrum is still affected) is 500 km. Since we know the density of this space (10^{-5} kgm^{-3}) and massial ratio of heavy metals in there (2%) we are able to evaluate the content of heavy metals in there in kilograms (0, 02.5.10^5.10^5.10^5 kg to 10^6 kg from the meteorite). The best terrestrial spectrographs are still able to recognize this change (the necessary condition in this case is, however, that the mass of the meteorite is dispelled into area less than 100x100 km^2. This is fulfilled (according to the high velocity of the meteorite) only when the meteorite flies on the connection line from the Earth to the Sun). This condition is fulfilled when the meteorite explodes as well (although the affected area must be photographed during the 0,1 s interval after the explosion - otherwise the mass is dispelled into a larger area than 100x100 km).

The Second Case - The Fall into the Photosphere

At first we must consider the fact that the meteorite must get there in some way – that means that the meteorite had to fly through the corona and, of course, that it was evaporating. In other words, in the beginninng its mass was approximatelly ten times greater. Firstly we should find how much the photosphere in the affected area will intensify by the change of the kinetical energy of the meteorite to the radiation. Let s find the area that will be two times brighter than its surrounding:

$$S = 4\pi m v^2 r^2 / 2W$$

We will find that the brightening would be observable for 1 second in the area of 55x55 km . The photosphere is about 500 km thick and the velocity of the meteorite is about 600 $km.s^{-1}$. At the same time, however, the density of the photosphere is much greater than that of the Corona and that is why the phenomena going on here will be explosing-like. Another parameter which affects the possibility of observation in smaller transparency of the photosphere. Despite all these negative influences the observation of this explosion can still be possible. (All the conditions mentioned above must be, however, fulfilled.)

Summary

We found that there is a possiblity to observe the mentioned phenomenon in both considered cases. The best way to observe it is however the spectrographic one. Of course, the exact trajectory of the meteorite must be known.

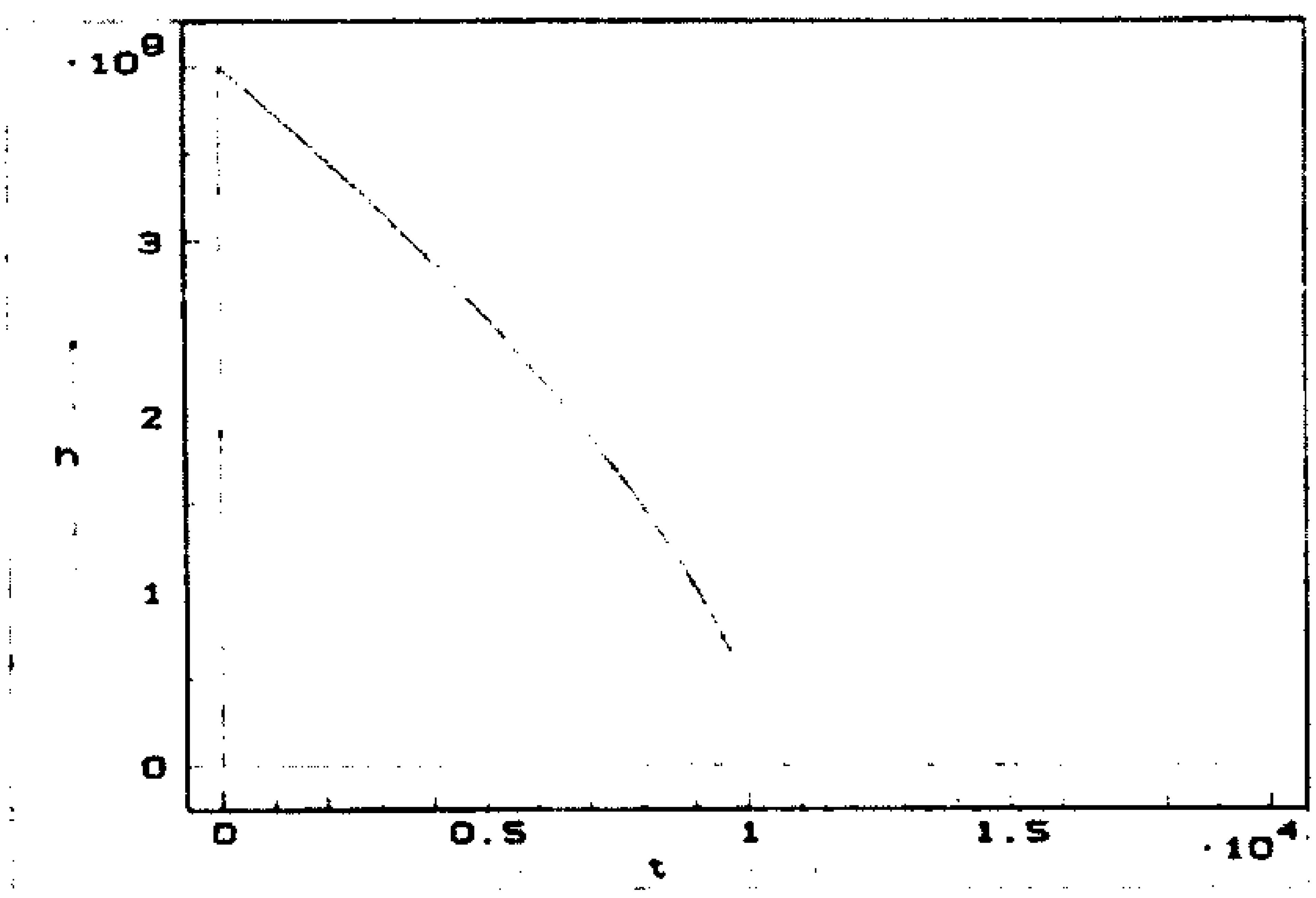

Fig.15 Dependence of the distance between the Sun and the meteorite on time

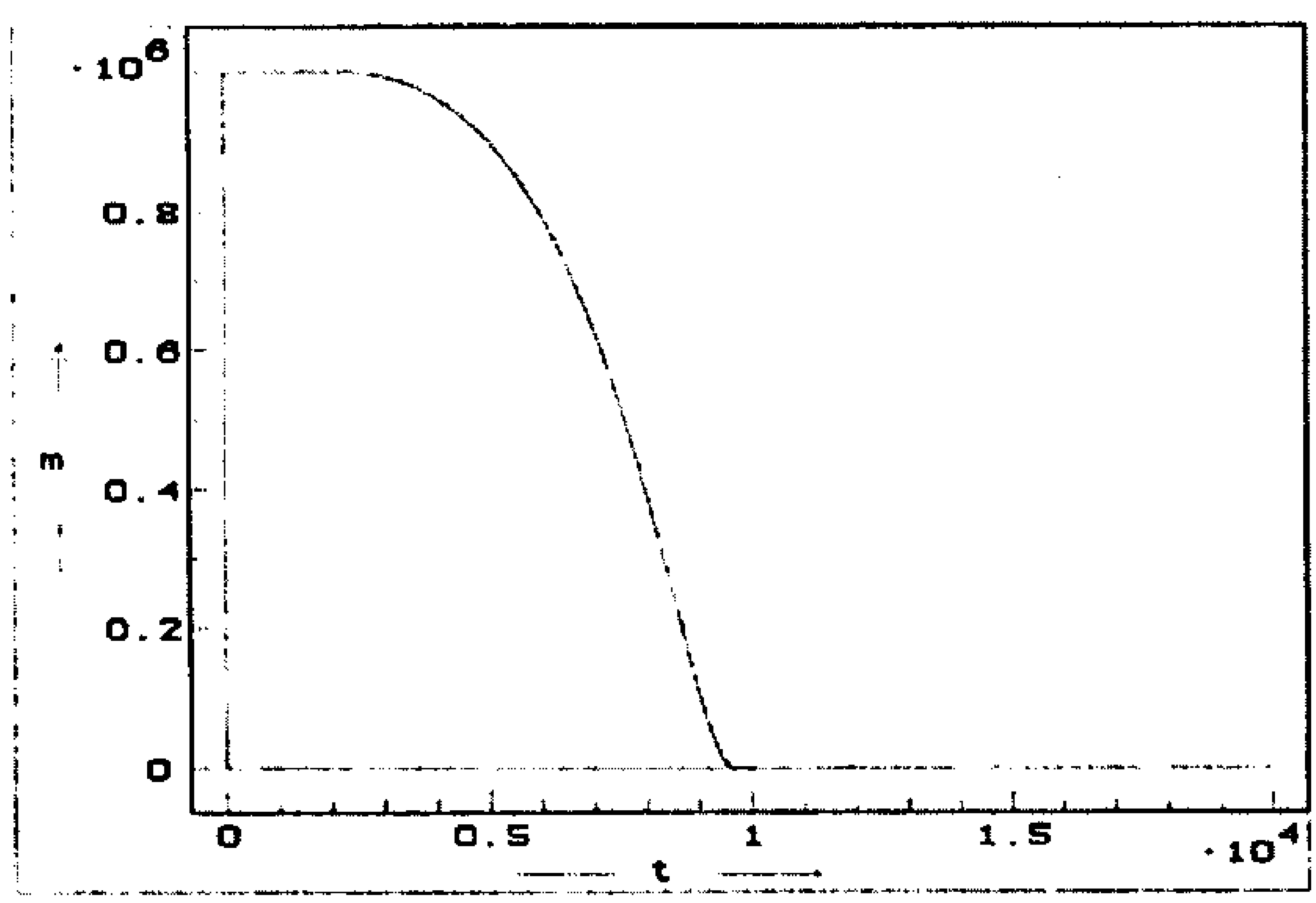

Fig.16 Dependence of the mass of the meteorite on the distance between the meteorite and the Sun

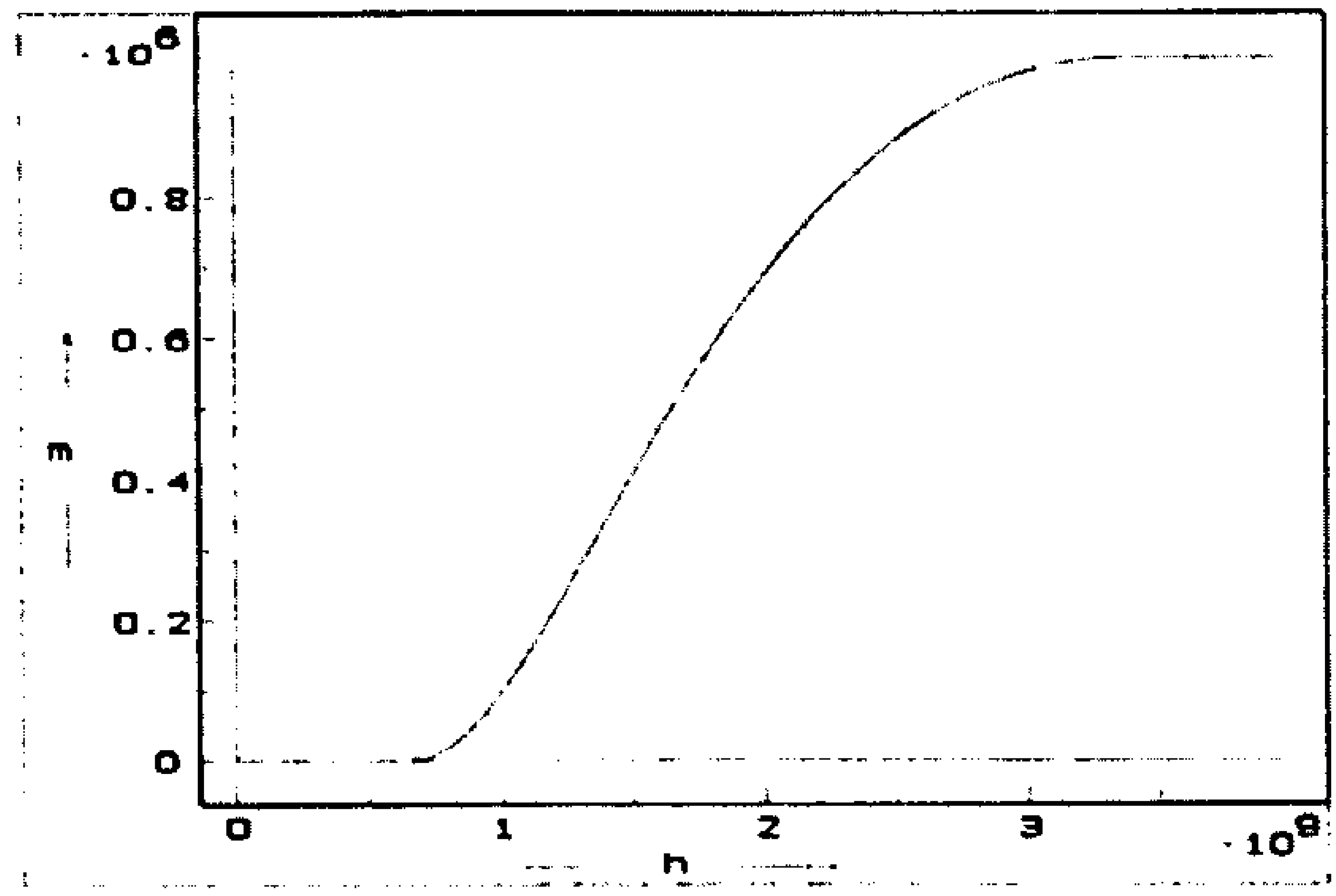

Fig.17 Dependence of the mass of the meteorite on time